(12) UK Patent Application (19) GB (11) 2 261 549 (13) A

(43) Date of A publication 19.05.1993

(21) Application No 9223021.8

(22) Date of filing 03.11.1992

(30) Priority data
(31) 03298895 (32) 14.11.1991 (33) JP

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(51) INT CL[5]
H01L 23/36 // H01L 23/02

(52) UK CL (Edition L)
H1K KPDC K1AA9 K1BC K4C5M K5A1 K5A3 K5D2 K5D9 K5N
U1S S2047

(56) Documents cited
GB 2026767 A EP 0081365 A1 US 4965660 A

(58) Field of search
UK CL (Edition K) H1K KPDC KPDX KPH
INT CL[5] H01L

(54) Cooling arrangement for a semiconductor module and manufacturing method thereof

(57) In a semiconductor module for use with an aluminum heat sink (17), thick-film resin (25) is directly coated onto the aluminum heat sink (17). A copper foil pattern (14) forms conductive passages on a surface of the thick-film resin (25). A semiconductor element (16) e.g. a power transistor is connected onto the copper foil pattern (14). Further, in a power control device for use with the semiconductor module, a control circuit section is mounted on portions of the thick-film resin (25), but isolated from the conductive passages formed by the copper foil pattern (14). The arrangement avoids the thermal stress which can result in bolted-on devices. The heat sink may have a honeycomb construction instead of fins.

FIG. 2

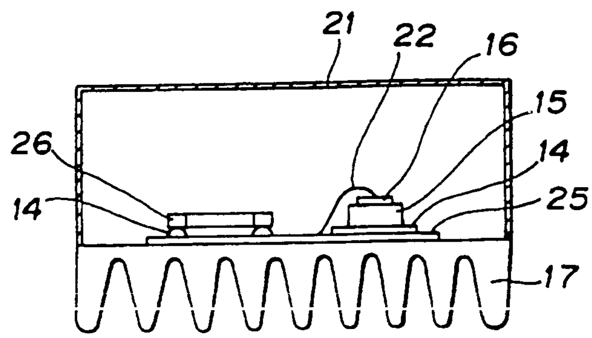

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FIG. 1

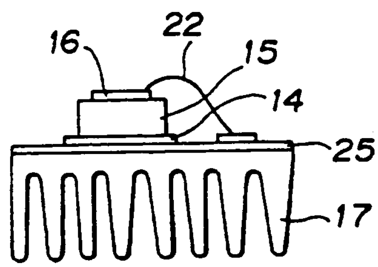


FIG. 2

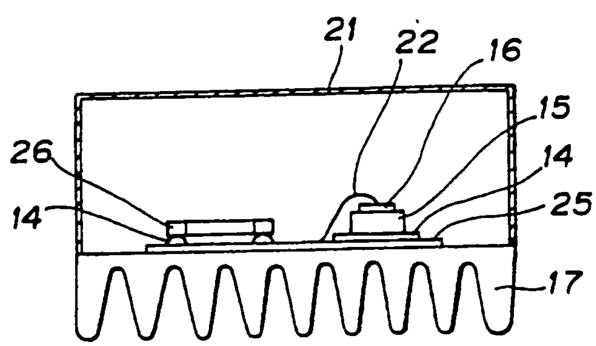


FIG.3 a

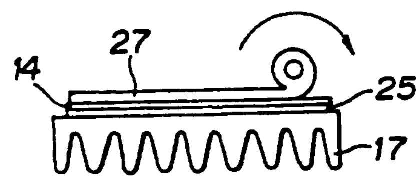


FIG.3 b

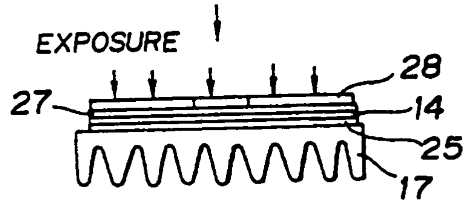


FIG.3 c

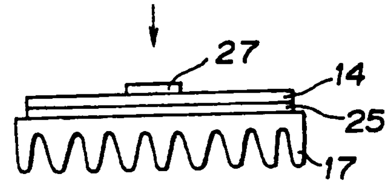


FIG.3 d

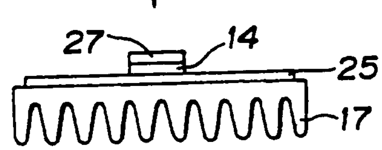


FIG.3 e

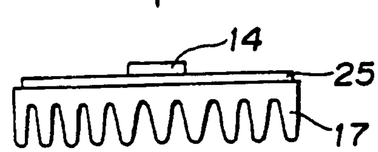


FIG.4a

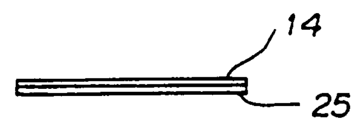


FIG.4b

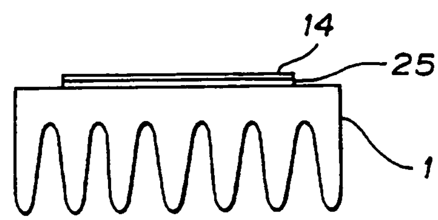


FIG.4c

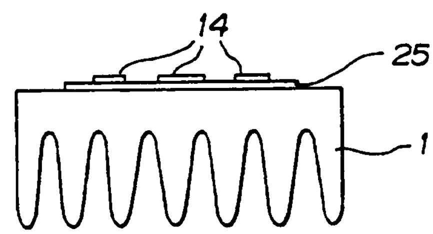


FIG.4d

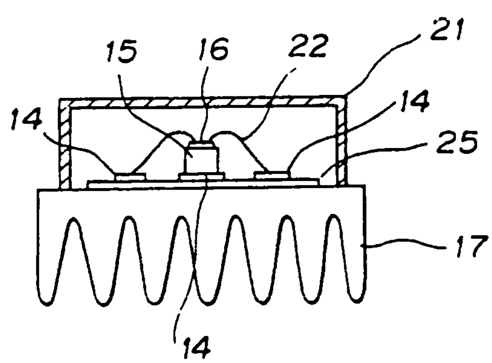


FIG. 5

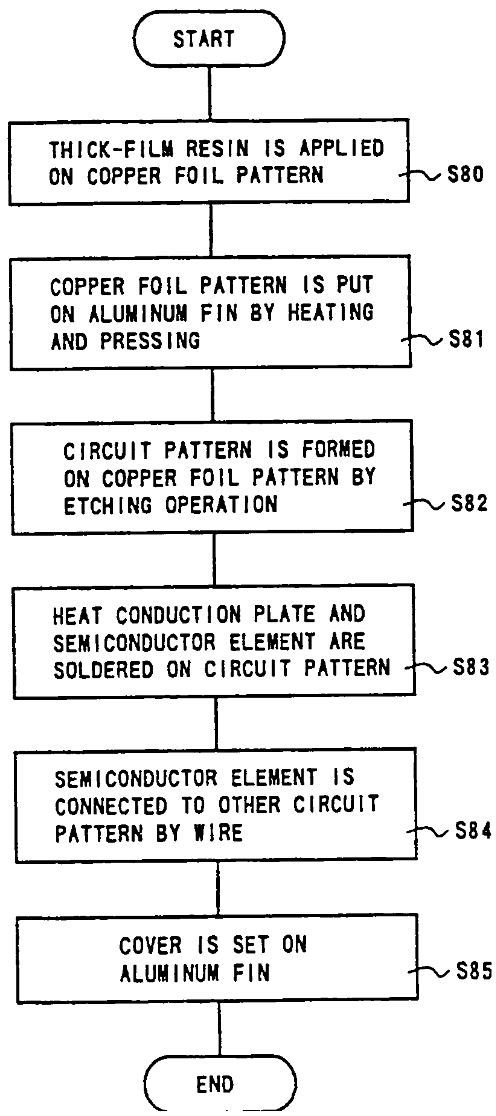

START
THICK-FILM RESIN IS APPLIED ON COPPER FOIL PATTERN
S80
COPPER FOIL PATTERN IS PUT ON ALUMINUM FIN BY HEATING AND PRESSING
S81
CIRCUIT PATTERN IS FORMED ON COPPER FOIL PATTERN BY ETCHING OPERATION
S82
HEAT CONDUCTION PLATE AND SEMICONDUCTOR ELEMENT ARE SOLDERED ON CIRCUIT PATTERN
S83
SEMICONDUCTOR ELEMENT IS CONNECTED TO OTHER CIRCUIT PATTERN BY WIRE
S84
COVER IS SET ON ALUMINUM FIN
S85
END

FIG.6

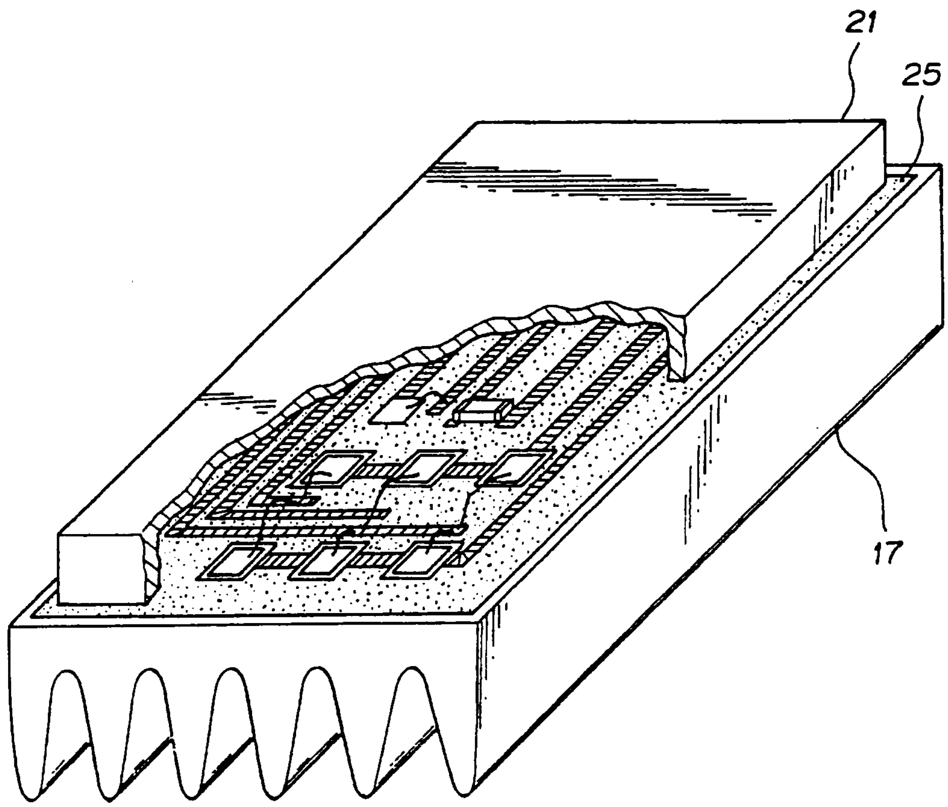


FIG. 7

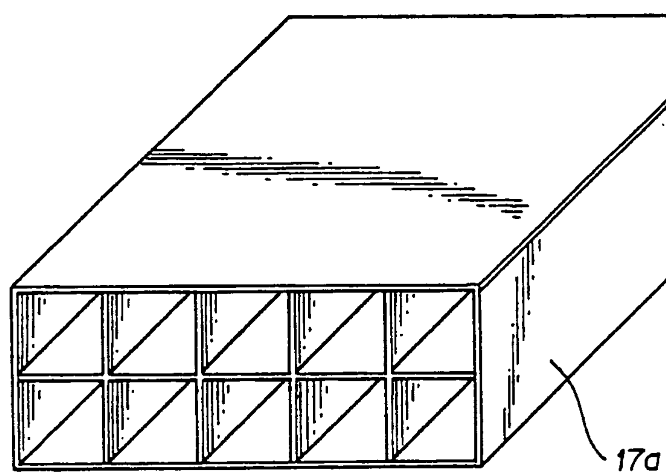


FIG. 8 PRIOR ART

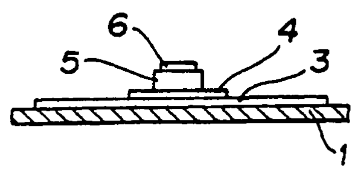
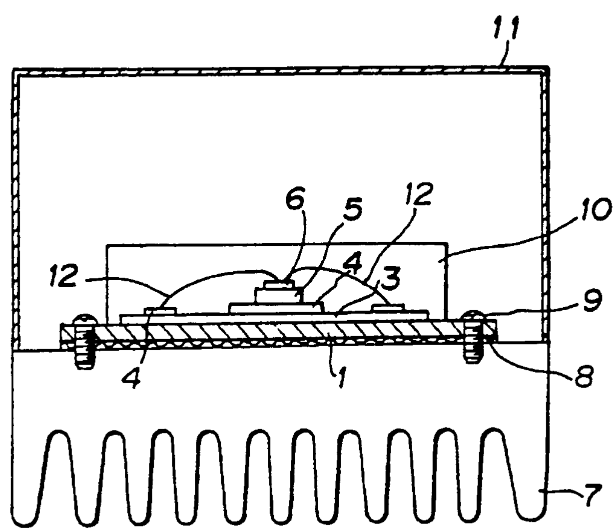


FIG. 9 PRIOR ART



8/11

FIG.10

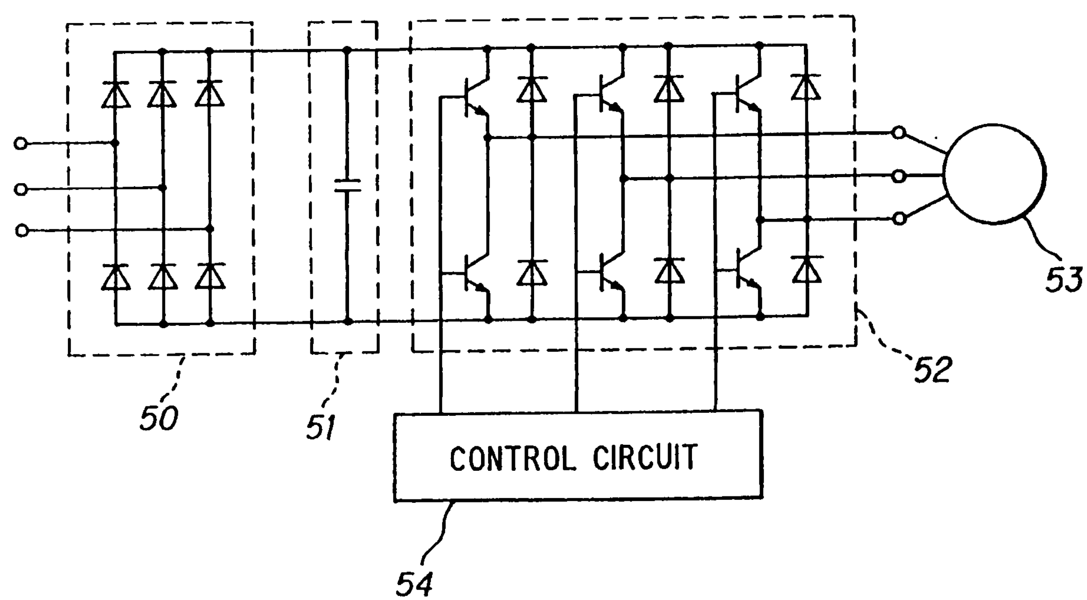


FIG. 11

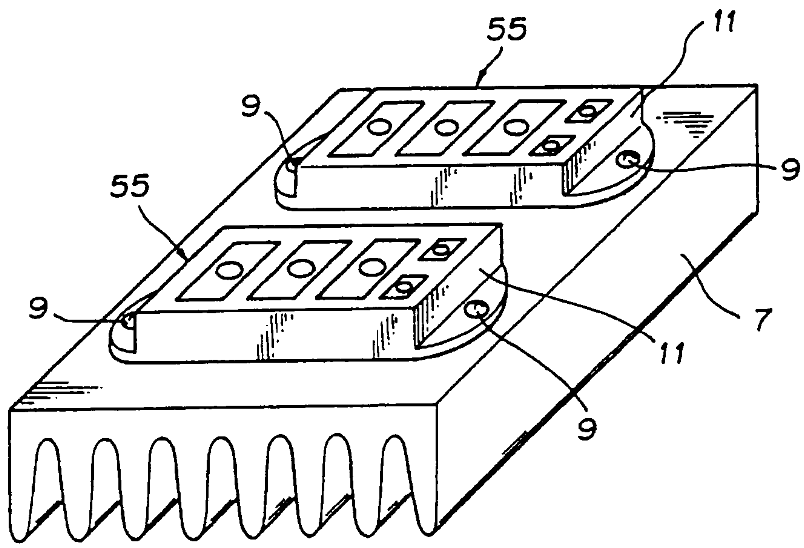


FIG. 12a

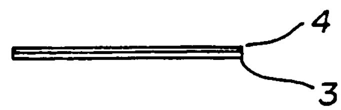


FIG. 12b

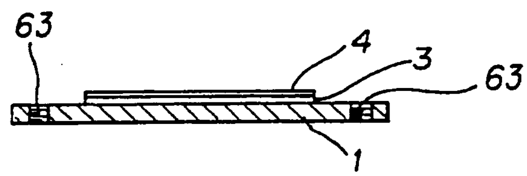


FIG. 12c

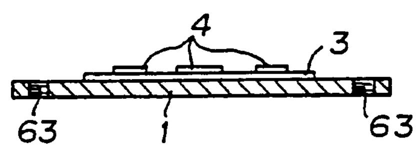


FIG. 12d

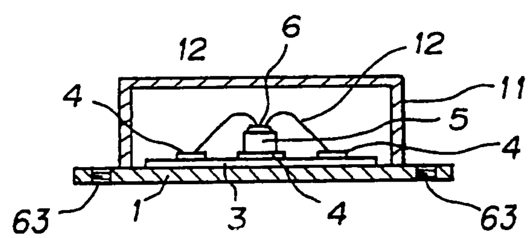


FIG. 12e

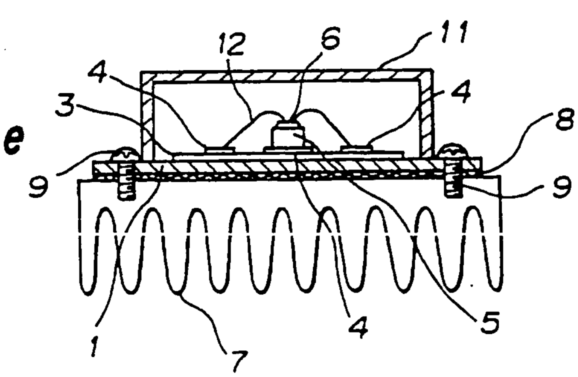
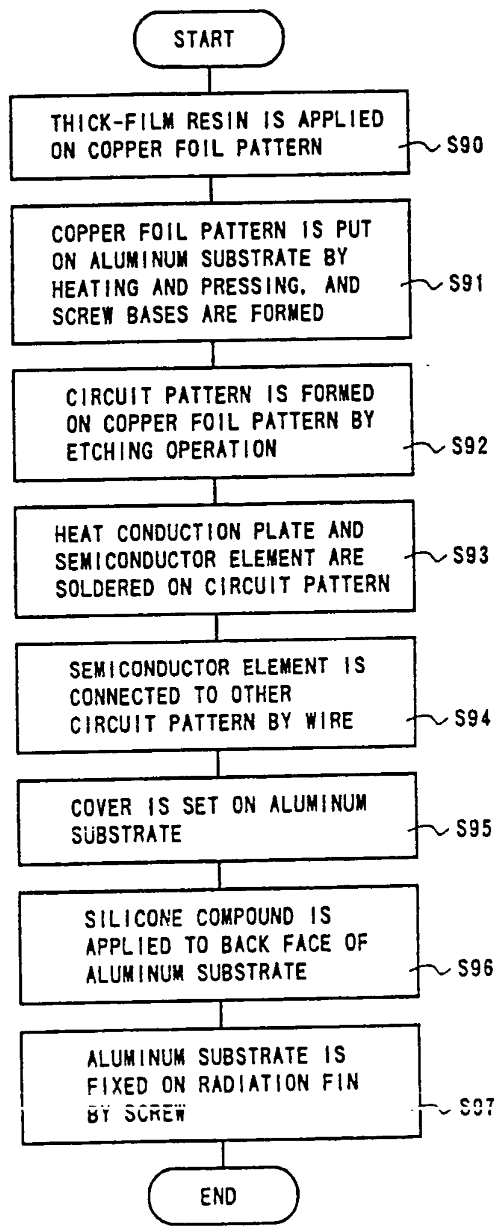


FIG. 13


START
THICK-FILM RESIN IS APPLIED ON COPPER FOIL PATTERN
S90
COPPER FOIL PATTERN IS PUT ON ALUMINUM SUBSTRATE BY HEATING AND PRESSING, AND SCREW BASES ARE FORMED
S91
CIRCUIT PATTERN IS FORMED ON COPPER FOIL PATTERN BY ETCHING OPERATION
S92
HEAT CONDUCTION PLATE AND SEMICONDUCTOR ELEMENT ARE SOLDERED ON CIRCUIT PATTERN
S93
SEMICONDUCTOR ELEMENT IS CONNECTED TO OTHER CIRCUIT PATTERN BY WIRE
S94
COVER IS SET ON ALUMINUM SUBSTRATE
S95
SILICONE COMPOUND IS APPLIED TO BACK FACE OF ALUMINUM SUBSTRATE
S96
ALUMINUM SUBSTRATE IS FIXED ON RADIATION FIN BY SCREW
S97
END

SEMICONDUCTOR MODULE AND POWER CONTROL DEVICE FOR USE THEREWITH AND MANUFACTURING METHOD THEREOF

FIELD OF THE INVENTION

This invention relates to a semiconductor module using a radiation fin and, more specifically, a power control device for use with the semiconductor module for an inverter apparatus, servo motor controller, or the like for driving a motor which produces alternate current of variable voltage and variable frequency. The invention also relates to a manufacturing method for the semiconductor module.

BACKGROUND OF THE INVENTION

Fig. 8 shows a principal arrangement of a circuit substrate which is disclosed, for example, in Japanese Patent Laid-Open No. HEI 2-209787. In Fig. 8, a polyamide film 3 is adhered to an aluminum substrate 1 by an adhesive layer. A plurality of conductive paths or passages are formed on the polyamide film 3 by a copper foil pattern 4. A semiconductor element 6 or the like is fixedly secured further onto the copper foil pattern 4 through a heat conduction plate 5, such as a copper piece or the like.

Fig. 9 shows a principal arrangement of an inverter apparatus which utilizes the circuit substrate illustrated in Fig. 8. As shown in Fig. 9, silicone compound 8 is applied to a rear or back face of the

aluminum substrate 1 in order to increase heat conduction. The aluminum substrate 1 is fixedly mounted on a radiation fin 7 by the use of screws 9. A mold package 10 protects the semiconductor element 6 on the aluminum substrate 1. The inverter apparatus has a cover 11 which protects the semiconductor module. The semiconductor element 6 is connected to the copper foil pattern 4 through a wire 12.

As described above, a silicone compound 8 is utilized to improve heat conduction. That is, if it is assumed that the aluminum substrate 1 and the radiation fin 7 are directly connected to each other by screws without the application of the silicone compound 8, a small air gap is defined between the aluminum substrate 1 and the radiation fin 7. Air has thermal conductivity of approximately 0.06×10^{-3} (cal/cm·s·°C) which is low. As a result, it is difficult to conduct heat across the gap.

Fig. 10 shows a circuit diagram of an inverter apparatus using semiconductor module shown in Fig. 9. In Fig. 10, a converter circuit 50 which commutates a commercial three-phase current is composed by six diodes. A smoothing condenser 51 smoothes an output from the converter circuit 50. An inverter circuit 52 converts a direct current smoothed by the smoothing condenser 51 to a three-phase alternating current of selectable voltage and frequency, and supplies it to a three-phase induction motor 53. In

the inverter circuit 52, three upper arm semiconductor switches and three lower arm semiconductor switches are connected in parallel to both terminals of the smoothing condenser 51, and the output from a connecting point of each upper arm semiconductor switch and lower arm semiconductor switch is inputted to the three-phase induction motor 53.

Each semiconductor switching element of the inverter circuit 52 is controlled ON/OFF by a control circuit 54, and outputs a three-phase alternating current pulse-duration modulated to the three-phase induction motor 53.

In the inverter apparatus, the converter circuit 50 and the inverter circuit 52 are heating elements and, accordingly, in a conventional apparatus, they are packaged as a power module 55 and are mounted on a radiation fin 7 as shown in Fig. 11.

Figs. 12a-12e and Fig. 13 show a process for making the conventional semiconductor module. In Fig. 12a, the polyamide film 3 (100 μm) is applied on the copper foil pattern 4 (35 μm)(step S90), and thereafter, in Fig. 12b, the copper foil pattern 4 is put on the aluminum substrate 1 (2-3mm) by heating and pressing, and screw bases are formed at the aluminum substrate 1 (step S91). In Fig. 12c, a circuit pattern is formed on the copper foil pattern 4 by an etching operation (step S92). In Fig. 12d, the heat conduction plate 5 and the semiconductor element 6 are soldered on

the circuit pattern (copper foil pattern 4)(step S93), the semiconductor element 6 is connected to other circuit pattern by using the wire 12 (step S94), and the cover 11 is set on the aluminum substrate 1 (step S95). Thereafter, in Fig. 12e, the silicone compound 8 is applied to a rear or back face of the aluminum substrate 1 (step S96). Finally, the aluminum substrate 1 is fixed on the radiation fin 7 by the screws (step S97).

The silicone compound is applied in paste form and includes a silicone oil or grease as a vehicle for a heat conductive metal-oxide. The thermal conductivity of the elemental silicone oil is approximately 0.4 x 10, and the thermal conductivity of the silicone oil which is added to the metal-oxide is approximately 1.5 x 10^{-3}(cal/sec · cm · ℃). The electrical conductivity of the silicone compound for insulation is approximately 10^{13}(Ω · cm).

In the conventional circuit substrate, the silicone compound is applied in order to improve heat conduction. However, thermal conductivity of the silicone compound is approximately 3.4 x 10^{-3}(cal/sec · cm · ℃). This is considerably less than the thermal conductivity of aluminum which is 486 x 10^{-3}(cal/sec · cm · ℃). Thus, there is a problem that utilization of the above-described arrangement has an undesirable radiation efficiency.

Further, when the silicone compound is

applied to the rear face of the aluminum substrate, the aluminum compound is applied to the entire rear face of the aluminum substrate as thin as possible. If, however, there is curvature in the aluminum substrate and the radiation fin, there may be portions to which the silicone compound is not applied. It is difficult to apply the silicone compound in proper quantity in accordance with the curvature every time. As a result, there is a problem that, if a gap is defined, a variation occurs in the heat conduction. In this connection, since a substrate curvature usually occurs when the screws are tightened, a gap is usually defined.

For the reason discussed above, careful control of the flatness of each of the aluminum substrate and the radiant fin, usually by management of the torque applied to the screws, is required. As a result, the number manufacturing steps is increased. Moreover, the elements which have an excessive curvature must be discarded. Thus, there is a problem that yield is low.

Further, if the silicone compound sticks to the fingers of an operator, the silicone compound may contaminate the products or work environment when touched by the operator. Thus, there is also a problem that the efficiency of the manufacturing process is deteriorated.

Furthermore, since the aluminum substrate and

the radiant fin are tightly secured each other by the screws, such that heat conduction is enhanced and no gap is created between the respective surfaces of the aluminum substrate and the radiant fin, if there is a curvature in each of the aluminum substrate and the radiant fin, stress is applied to soldered sections of the semiconductor element and the copper foil pattern when the screws are tightened. This leads to breakage of the semiconductor element, separation of the semiconductor element from the pattern, cracking of the pattern, and the like. Thus, there is a concern that the conventional apparatus may be easily damaged. In view of this, severe flatness management of the aluminum substrate and the radiant fin, and severe screwing torque management are required. However, as a practical matter, it is quite difficult to minimize the breakage and the like problems above-described.

Finally, a space must be formed for screw bores on the aluminum substrate. As a result, the area, which can be used for packaging or mounting of parts and the pattern, is narrowed. In order to produce a power control device which has desired properties, the aluminum substrate must be enlarged. Thus, there is also a problem that miniaturization of the power control device is hindered or impeded.

SUMMARY OF THE INVENTION

It is therefore an object of the invention to

provide a semiconductor module in which heat conduction efficiency is improved, in which the consistency of heat conduction is improved, in which a strict management of the flatness of an aluminum substrate and a radiation fin and a strict management of torque applied to screws is unnecessary, in which manufacturing yield is improved, and in which an attempt is made to promote miniaturization.

It is another object of the invention to provide a power control device which uses the above-described semiconductor module.

In the semiconductor module and the power control device according to the invention, the electrically insulating resin is directly coated on the radiation fin. The conductive passages are formed on the surface of the electrically insulating resin, by the copper foil pattern. The power semiconductor element is connected onto the copper foil pattern.

With the arrangement of the invention, since a layer of silicone compound can be omitted, it is possible to greatly improve conductivity of heat generated at the power semiconductor element. Thus, there is produced an advantage that the service life of the apparatus can be prolonged. Further, variations in heat conduction can be eliminated, and a screwing step is unnecessary. Accordingly, there is no application of stress to the element or the pattern due to curvature. Thus, there is produced an advantage that

reliability of the apparatus can be improved. Moreover, since insurance of a space for screw bores required for screwing is unnecessary, the effective area for use in the packaging of various elements increases so that miniaturization of the apparatus is promoted. Since the trouble of applying the silicone compound can be saved, there is produced an advantage that manufacturing yield and cost can be improved.

Other objects and features of this invention will become understood from the following description with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows a summarized arrangement of a semiconductor module according to the invention;

Fig. 2 shows a summarized arrangement of a power control device according to the invention, which uses the semiconductor module shown in Fig. 1;

Fig. 3a through 3e shows a method of etching, according to the invention;

Fig. 4a through 4d shows a summarized arrangement of a making process of a semiconductor module according to the invention;

Fig. 5 shows a flow chart of a making process of a semiconductor module according to the invention;

Fig. 6 shows a perspective view of a semiconductor module according to the invention;

Fig. 7 shows a perspective view of a

radiation fin formed into honeycomb type.

Fig. 8 shows a summarized arrangement of a conventional semiconductor module;

Fig. 9 shows a summarized arrangement of a power control device which uses the conventional semiconductor module shown in Fig. 8;

Fig. 10 shows a circuit diagram of a conventional inverter apparatus;

Fig. 11 shows a perspective view of a conventional semiconductor module;

Fig. 12a through 12e shows a summarized arrangement of a process for making a conventional semiconductor module; and

Fig. 13 shows a flow chart of a making process of a conventional semiconductor module.

DESCRIPTION OF THE EMBODIMENTS

Referring first to Fig. 1, there is shown an arrangement of a semiconductor module according to the invention. The semiconductor module comprises electrically insulating thick-film resin 25, for example, epoxy resin which is directly coated on an aluminum fin 17 for heat conduction. A copper foil pattern 14 is printed on the thick-film resin 25 in order to form conductive paths or passages. A naked or uncovered chip of a semiconductor element 16, such as a power transistor, an IGBT, a diode and the like, is packaged in soldering onto the copper foil pattern 14

through a heat conductive plate 15. The semiconductor element 16 is connected to the copper foil pattern 14 by a wire 22.

Fig. 2 shows an arrangement of a power control device which utilizes the semiconductor module illustrated in Fig. 1. A control circuit section 26 is packaged in soldering to sections other than the conductive passages formed by the copper foil pattern 14. In addition, the semiconductor element 16 is packaged in soldering onto the copper foil pattern 14. A cover 21 establishes a protected interior for housing the power control device.

An example of a method of coating an insulator, such as the epoxy resin (thick-film resin 25) or the like, on to the aluminum fin 17 will next be described. First, an adhesive varnish consisting of alumina powder, epoxy resin, hardening agent, solvent and the like is uniformly applied to the copper foil, and is dried. Here, the alumina powder is used in order to improve heat conductivity of the resin film 25. Thereafter, the copper foil to which the adhesive varnish is applied is pasted on to a surface of the aluminum fin 17 which has a surface processed in plane polishing, such that the adhesive faces toward the aluminum fin 17. Subsequently, the copper foil and the aluminum fin 17 are heated and pressed against each other. Thus, the copper foil is coated on the surface of the aluminum fin 17.

A method of insulating the aluminum fin 17 due to surface oxidization will next be described. A stable oxide layer is easily formed on a surface of aluminum within an oxygen atmosphere. In order to improve corrosion resistance, however, in the case where a thicker oxide film is intentionally formed, there are an anodic oxidation method and a chemical film conversion processing or treating method using chemicals.

The anodic oxidation method is arranged as follows. That is, in an electrolyte of 2% of oxalic acid or of 15% of sulfuric acid, an aluminum product is brought to an anode of direct-current electrolysis and, further, alternate current is superimposed upon the aluminum product, to form an anodic film (an alumite layer). Further, the chemical film conversion processing or treating method is arranged as follows. That is, for example, an aluminum product is dipped in aqueous solution of approximately 5% of sodium carbonate for a period of time of the order of 20 ~ 30 minutes.

A method of etching will next be described. Figs. 3a through 3e show various steps of the etching method. As shown in Fig. 3a, the thick-film resin 25 for electric insulation, for example, epoxy resin is directly coated on the aluminum fin 17. In order to form the conductive passages, a dry film 27 is laminated on the copper foil 14 which is printed on the

[redacted]

thick-film resin 25. At this time, a lamination for temperature is 90 ~100 ℃ a pressure is 2 ~4 kg/cm^2, and a speed is 1.0 ~2.0 m/min.

Subsequently, as shown in Fig. 3b, a negative-pattern mask 28 is covered on the dry film 27, and exposure processing is executed by a high-pressure mercury lamp, for example. Subsequently, as shown in Fig. 3c, the negative-pattern mask 28 is removed. Portions of the dry film 27, which are shaded from light, are removed. The remaining portions of the dry film 27 are developed, using a liquid developer, and form a hardened resist.

Subsequently, as shown in Fig. 3d, portions of the copper foil 14, which are not protected by the dry film 27 (at unnecessary portions), are dissolved by solution of iron chloride or copper chloride, to execute etching. Lastly, as shown in Fig. 3e, the dry film 27 (hardened resist) is separated, leaving a desired copper pattern on the thick-film resin 25.

Figs. 4a-4d and Fig. 5 show making process of the semiconductor module according to the invention. In Fig. 4a, the thick-film resin 25 is applied on the copper foil 14 (step S80). Thereafter, in Fig. 4b, the copper foil 14 is put directly onto a surface of the aluminum fin 17 by heating and pressing (step S81). In Fig. 4c, a circuit pattern is formed on the copper foil 14 by the etching operation shown in Figs. 3a-3e (step S82). In Fig. 4d, the heat conduction plate 15 and the

semiconductor element 16 are soldered on the circuit pattern (copper foil pattern 14)(step S83), and the semiconductor element 16 is connected to other circuit pattern by using a wire 22 (step S84), and the cover 21 is set on the aluminum fin 17 (step S85). Fig. 6 is a perspective view showing a state that plural semiconductor modules are set on the aluminum fin 17, and Fig. 7 is a perspective view showing a shape of a radiation fin 17a formed into a honeycomb type.

Although the invention has been described with respect to a specific embodiment for a complete and clear disclosure, the appended claims are not to be thus limited but are to be construed as embodying all modifications and alternative constructions that may occur to one skilled in the art which fairly fall within the basic teaching herein set forth.

WHAT IS CLAIMED IS:

1. A semiconductor module having a housing defining an interior and heat sink means closing said interior and comprising a conductive radiation fin , said module further comprising:

an electrical insulator directly formed on said heat sink means and defining an interior surface;

a copper foil pattern forming a plurality of conductive passages on said interior surface of said electrical insulator ; and

a semiconductor element connected onto said copper foil pattern .

2. A semiconductor module according to claim 1, wherein said electrical insulator comprises surface oxidization of said heat sink means.

3. A semiconductor module according to claim 1, wherein said electrical insulator comprises epoxy resin.

4. A semiconductor module according to claim 1, further comprising a heat conductive plate through which said semiconductor element is connected to said copper foil pattern .

5. A semiconductor module according to claim 1, wherein said semiconductor element comprises one of a power transistor, an IGBT and a diode.

6. A semiconductor module according to claim 1, wherein said radiation fin has a honeycomb structure.

7. A manufacturing method for a semiconductor module comprising the steps of:

applying an electrically insulating resin onto a first surface of a copper foil;

applying said resin-coated surface of said copper foil onto a heat sink surface by heating and pressing;

forming a circuit pattern on said copper foil comprising at least first and second electrical conductors;

soldering at least a heat conduction plate and a semiconductor element to said copper foil pattern;

electrically connecting said semiconductor element to said at least first and second conductors by using a wire; and

attaching a cover to said heat sink to enclose at least said semiconductor element.

8. A manufacturing method of the semiconductor

module, as set forth in claim 7, wherein said applying step comprises coating an epoxy resin onto said copper foil.

9. A manufacturing method of the semiconductor module, as set forth in claim 7, wherein said applying step comprises forming an oxidized aluminum film by surface oxidization of said heat sink.

10. A power control device for use with a semiconductor module, comprising:

a radiation fin comprising a first surface;

electrically insulating resin directly coated on said radiation fin first surface and forming a coated surface;

a copper foil pattern forming a plurality of electrical conductors on said coated surface of said electrically insulating resin ;

a power semiconductor element packaged in soldering onto said copper foil pattern ; and

a control circuit section packaged in soldering to at least a portion of said surface of said electrically insulating resin , except for said electrical conductors.

11. A power control device according to claim 10, wherein said radiation fin comprises an aluminum

fin.

12. A power control device according to claim 10, wherein said electrically insulating resin comprises epoxy resin.

13. A power control device according to claim 10, wherein said copper foil pattern comprises a printed pattern on said electrically insulating resin .

14. A power control device according to claim 10, further comprising a heat conductive plate through which said semiconductor element is connected to said copper foil pattern .

15. A power control device according to claim 10, wherein said semiconductor element comprises one of a power transistor, an IGBT and a diode.

16. A power control device according to claim 10, wherein said radiation fin comprises honeycomb structure.

17. A power control device according to claim 11, wherein said radiation fin first surface comprises an insulating oxide.

18. A semiconductor module, substantially as herein described with reference to figures 1 and 4a to 6 of the accompanying drawings.

19. A power controller device substantially as herein described with reference to figures 1 to 6 of the accompanying drawings.

20. A method of making a semiconductor module, substantially as herein described with reference to figures 4a to 5 of the accompanying drawings.

-19-

Patents Act 1977
E. .miner's report to the Comptroller under Section 17 (The Search Report)

Application number
GB 9223021.8

Relevant Technical fields

(i) UK Cl (Edition K) H1K (KPDC KPDX KPH)

(ii) Int Cl (Edition 5) H01L

Databases (see over)

(i) UK Patent Office

(ii)

Search Examiner
R C HRADSKY

Date of Search
2 DECEMBER 1992

Documents considered relevant following a search in respect of claims 1-20

Category (see over)	Identity of document and relevant passages		Relevant to claim(s)
Y	EP 0081365 A1	(HITACHI) whole document	1, 7, 10
Y	GB 2026767 A	(OCL) Figures 2, 4 and page 2 lines 30-73	1, 7, 10
Y	US 4965660	(HITACHI) Figure 2, column 3 line 49 - column 4 line 8	1, 7, 10

Category	Identity of document and relevant passages	Relevant to claim(s.

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family, corresponding document.

Databases: The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases